Estimating the Duration of Aqueous Events on Mars from Petrology and Geochemistry of Alteration Products

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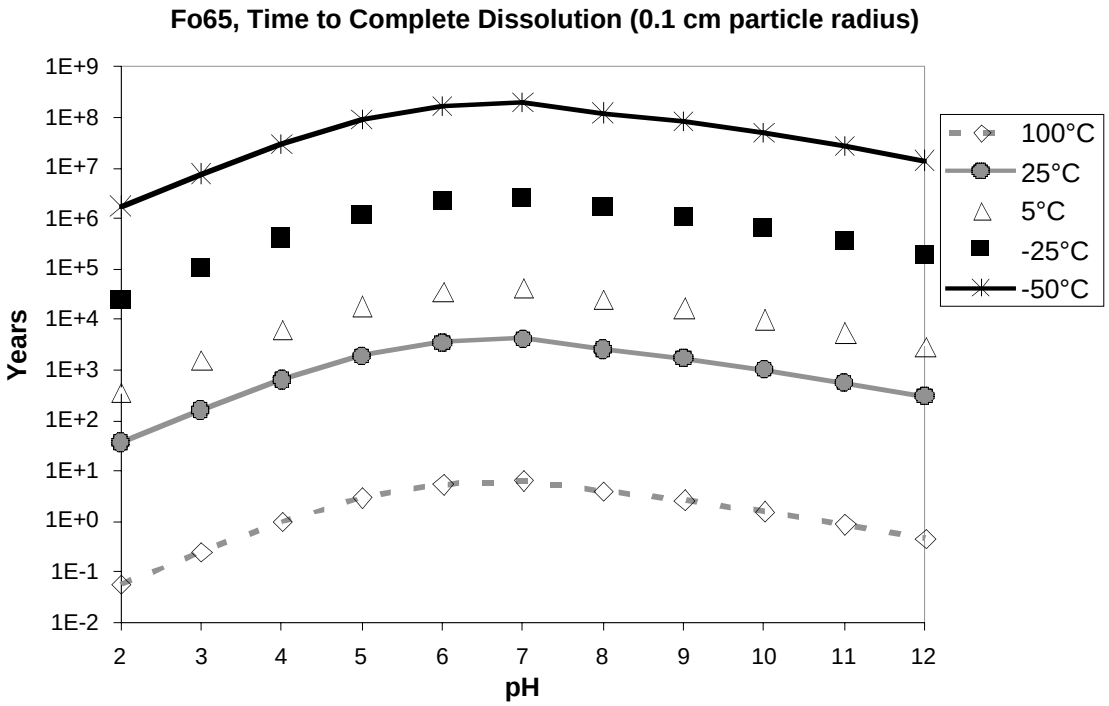
Orbital, landed, and meteorite data show that liquid water shaped the Martian surface, raising the possibility that life could have originated. An important question is how long each epoch of wet conditions lasted. The duration can be inferred from mineralogy and chemical composition of surface materials, from millimeter to multi-kilometer scales. The products formed during wet periods depend on crustal composition, mineral dissolution, temperature, water chemistry, pH, and rock/water ratio. Dissolution rates have been measured in both the laboratory and the field. Studies show that dissolution rates are 100 to 10,000 times slower in the field than ideal laboratory conditions. This difference is largely controlled by rock permeability and local rock/water ratio. Nevertheless, laboratory studies can provide useful lower limits for the duration of aqueous events on Mars. We calculate that areas rich in olivine sands (such as at Meridiani Planum) could not have been exposed to water for more than a few thousand years at conditions far from equilibrium. For example, the residence time of a 0.1 cm (radius) particle of Fo65 composition at 25°C ranges from ~40 years at pH 2 to ~4,000 years at pH 7 (see figure). At lower temperature (5°C), dissolution of the same particle will take ~10 times longer. We also use observations of Martian meteorites to gain insight into alteration processes on Mars and the nature of incipient alteration. MIL 03346 (a nakhlite) shows incipient alteration of olivine, providing clues into the difference between laboratory and field rates.


Fo65, Time to Complete Dissolution (0.1 cm particle radius)
Years
1E+9
1E+8
1E+7
1E+6
1E+5
1E+4
1E+3
1E+2
1E+1
1E+0
1E-1
1E-2
2
3
4
5
6
7
8
9
10
11
12
pH
100°C
25°C
5°C
-25°C
-50°C